SMWD 2023, KTH Royal Institute of Technology, Stockholm, 23rd - 25th May 2023

Dynamic Gate Bias to Improve PAE of Power Amplifiers with Telecommunications Signals

Göksu Kaval [1][2], Gregor Lasser[1], Marcus Gavell[2], and Christian Fager[1]
(1) Chalmers University of Technology
(2) Gotmic AB, Göteborg, Sweden

Summary

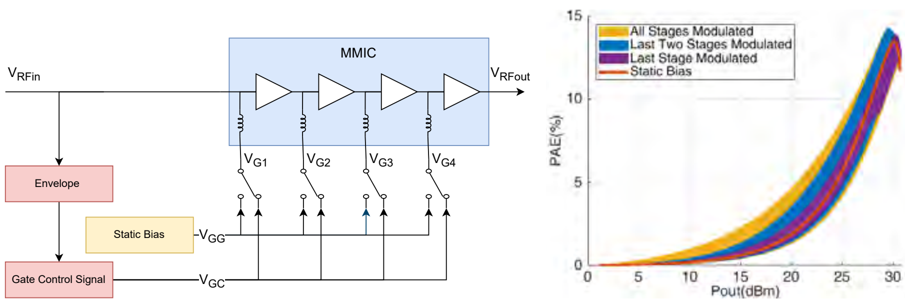
In this work, linear power tracking-based gate modulation of one or several stages of an E-Band PA was studied to improve the average PAE with telecommunication signals. The method improved PAE from 3.34%to 7.39% based on quasi-static modulated signal simulations.

1 Introduction

To support high data rates and spectral efficiency telecommunications systems utilize higher-order modulation schemes. These modulation formats use signals with high dynamic range and peak-to-average ratio. On the other hand, many power amplifiers(PA) at the transmitter front ends are biased for class- A or class AB to be able to deliver high-output power. However, the PAE of these PAs decreases with increasing back-off levels. As a result, the average PAE of these PAs, when they are used with telecommunications signals, is less than their peak PAE. In this work, different numbers of gates of a four-stage PA were dynamically biased based on instantaneous input power to improve average PAE with modulated signals.

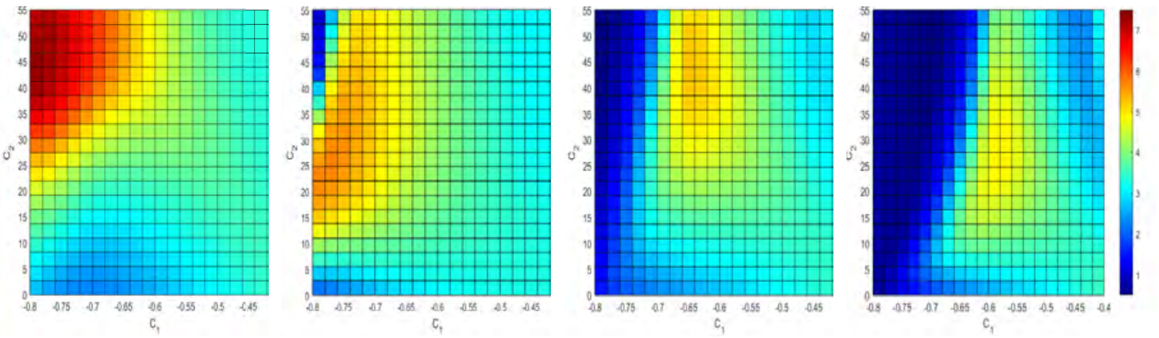
2 Gate Drive Functions Based on Efficiency Optimization with Telecommunications Signals

As shown in Figure 1a, dynamic gate biasing of the last stage, the first stage, the last two stages and all stages of a four-stage PA were studied. For each case, all gates were dynamically biased based on a single control voltage (V_{GC}) which was generated based on the instantaneous envelope information and the rest of the gates were kept at a nominal gate bias level of -0.46 V corresponds to $250 mA/mm$. For the studies, a 1W 100nm GaAs gAPZ00092 PA designed by Gotmic AB for E-Band were simulated in ADS Harmonic Balance. Input power and modulated gate bias voltages were swept. Output power and power consumption were modelled as a function of input power and gate bias voltage. Figure 1b shows possible PAE ranges at each output power level with different numbers of gates modulated. One can see that as the greater number of gates modulated more power-added efficiency could be acquired. While a greater number of modulated gates bring the possibility of acquiring higher PAE at each output power level, it was discussed in [1] selecting the gate bias voltage that brings maximum PAE at each output power does not necessarily bring maximum average PAE when tested with telecommunications signals since it deteriorates the linearity of PA significantly. To investigate the trade-off between linearity and PAE a quasi-static telecommunication simulation was implemented.To do so, a bit stream was modulated in the QAM64 modulation scheme at $50 MSymbol/s$ symbol rate and root-raised cosine filtered with a roll-off factor of 0.25. The resulting waveform was fed gate modulated PA model based on continuous wave simulations. Output power was increased until the output spectrum reaches to the ETSI spectrum emission mask for a 62,5MHz bandwidth signal at E-Band.



(a) **(b)**

Figure 1. (a) Functional Schematic of Studied Structure (b) Achievable PAE with modulating the different number of gates



(a) (b) (c) (d)

Figure 2. Grid of power tracking coefficients and resulting PAE at mask limit, for (a)the last stage gate modulated PA, (b)the first stage gate modulated PA, (c)the last two stages gates modulated PA, (d)all stages gates modulated PA.

Considering the testability of the results for further works gate bias signal was selected as a bandwidth-reduced linear power tracking signal described in [2]. In other words, the gate bias signal was defined as a first-order polynomial of instantaneous input power as

$$V_{\mathrm{GC}} = C_1 + C_2 P_{\mathrm{inst}}. \tag{1}$$

where P_{inst} stands for instantaneous input power. This reduces the problem to finding the optimum C_1 and C_2. To see the effects of these coefficients, grids of C_1 and C_2 were constructed for each case and average PAE ($\overline{PAE}$) at mask limit for each grid point was simulated based on quasi-static telecommunications signal simulations. As can be seen in Figure 2a, 2c and 2d for each case there are some regions that provide better PAE compared to static bias case which corresponds to $C_2 = 0$ line. The C_1 and C_2 pairs that bring maximum $\overline{PAE}$ was given as a seed to MATLAB's optimization tools to find the actual maximum point and resulting coefficients, $\overline{PAE}$ and average output power($\overline{P_{\mathrm{out}}}$) were tabulated in Table 1.

Table 1. Quasi-Static Simulation Results at Spectrum Mask Limit

	C_1	C_2	$\overline{PAE}$	$\overline{P_{\mathrm{out}}}$	$\overline{P_{\mathrm{DC}}}$
Static Bias(Nominal)	-0.46	0	3.34	22.59	5.39
Last Stage	-0.797	45	7.39	25.70	4.97
First Stage	-0.796	24	5.70	24.88	4.83
Last Two Stages	-0.657	42	5.24	23.52	4.25
All Stages	-0.591	24	4.93	23.26	4.26

$\overline{PAE}$ in %, $\overline{P_{\mathrm{out}}}$ in dBm and $\overline{P_{\mathrm{DC}}}$ in Watt

3 Conclusion

In this work linear power tracking-based gate modulation of different stages of a PA was studied to improve the $\overline{PAE}$ with modulated signals. Unlike the previous work, gate bias functions were not selected to maximize continuous-wave PAE. Instead, the effects of bandwidth-reduced gate bias function coefficients were investigated under quasi-static telecommunications simulations to monitor the tradeoff between linearity and PAE improvement to select optimum coefficents. The study shows that correctly determined gate bias functions were able to increase PAE from 3.34% to 7.39%. Moreover, increased output power at the mask limit implies linearity of the PA was also improved by using dynamic gate biasing.

References

[1] G. Kaval, G. Lasser, M. Gavell, and C. Fager, "Multi-stage gate modulation of e-band mmic power amplifier for efficiency improvement," in *2022 International Workshop on Integrated Nonlinear Microwave and Millimetre-Wave Circuits (INMMiC)*, 2022, pp. 1–3.

[2] M. Olavsbråten and D. Gecan, "Linearity and efficiency enhancement of gan pas using bandwidth reduced dynamic gate and drain supply modulation (pet)," in *2018 IEEE 19th Wireless and Microwave Technology Conference (WAMICON)*. IEEE, 2018, pp. 1–4.